# Geology

The following discussion of geology is adapted USBR (1969). The Sites Reservoir is on the west side of the Sacramento Valley in the foothills of the Coast Ranges. The area is underlain by Lower and Upper Cretaceous sedimentary rocks of the Great Valley Sequence folded along northerly trending axes and cut by north- and northeast-striking faults. The regional geology is shown in Figure 4.

The major structural features in the region include the Sites anticline, a major anticlinal flexure on the west side of the Sacramento Valley that passes through the long axis of the reservoir and is paralleled to the west by a broad shallow syncline, called the Fruto syncline. The Salt Lake fault parallels the axis of the anticline near the center of Antelope Valley. The Sites anticline is interpreted by Phipps and Unruh (1992), as a major, west-vergent thrust (Salt Lake fault) juxtaposing moderately to steeply east-dipping rocks in its hanging wall against the west-dipping east limb of the Fruto syncline, which plunges to the north. The Salt Lake fault is known from south of Cache Creek to west of Willows and is a bedding plane fault in its hanging wall. The fault is steeply cross cutting in its foot wall near Sites and approaches bedding plane geometry towards the south (Leesville grade to Cache Creek canyon).

## **Great Valley Sequence**

The Sites and Golden Gate dam sites are on the eastern flank of the Sites anticline near the contact between the Venado sandstone member of the Cretaceous Cortina Formation and the underlying siltstone/mudstone of the Boxer Formation. The contact between the Boxer and the Cortina is generally taken to be the lowest major sandstone unit.

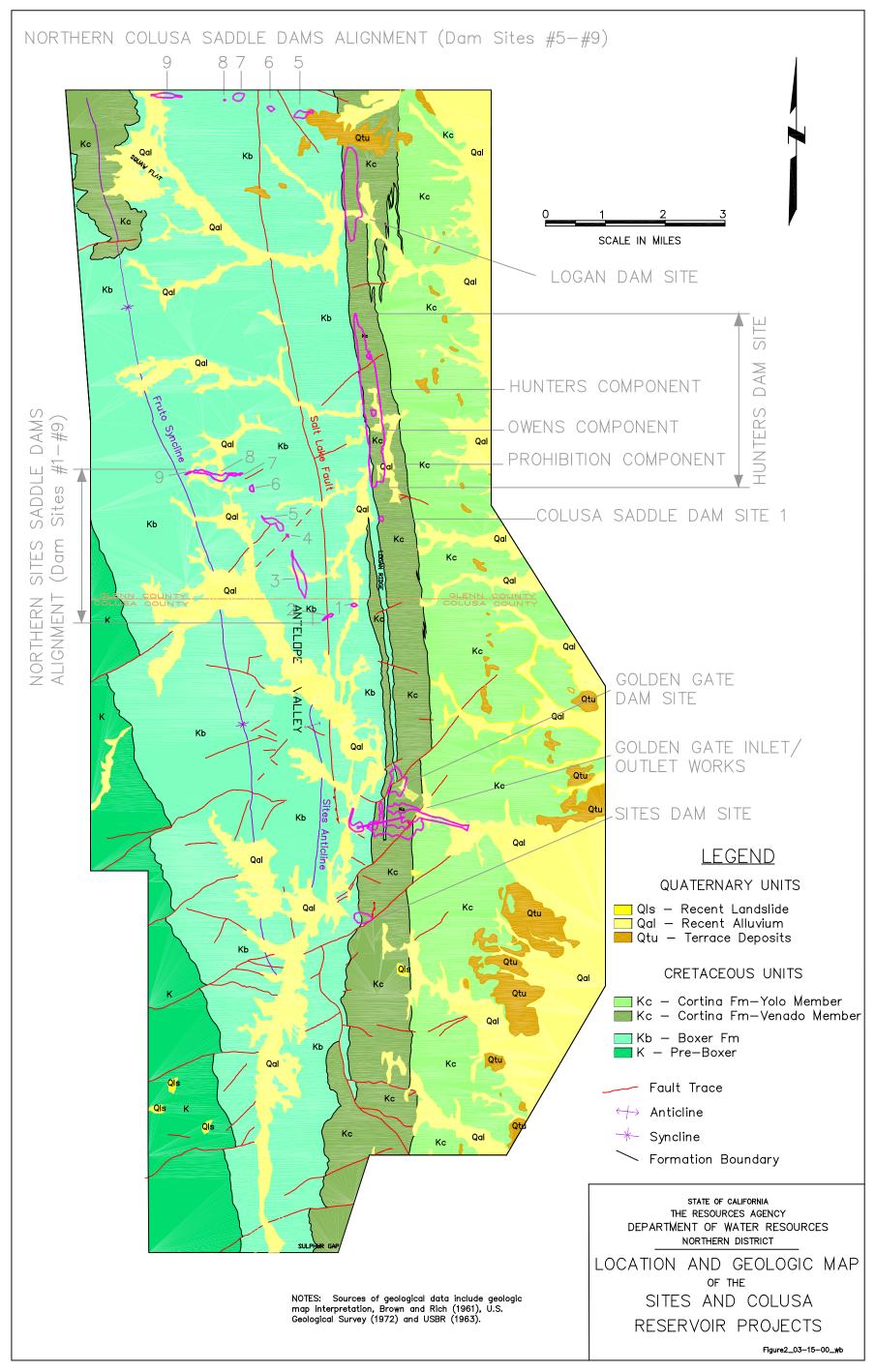
The Boxer Formation consists of thin bedded mudstone with scattered thin to medium sandstone interbeds representative of basin-plain deposits of distal turbidites. The base of the Boxer Formation includes the Salt Creek conglomerate member but it is not exposed in this area (Ingersoll 1981). The Boxer Formation is less resistant to weathering and erosion, underlies the valley east of the sandstone ridges of the Venado, and makes up the core of the Sites anticline.

The Cortina Formation includes three mapped members, the Venado sandstone, the Yolo shale, and the Sites sandstone. The basal unit of the Venado sandstone is primarily fine- to medium-grained, hard, and occurs chiefly in 1- to 10-foot-thick beds. Petrographic studies indicate that the rock is cemented by carbonates and by a silica-clay matrix. The Venado includes a lesser amount of well indurated, crudely fissile mudstone that occurs as 1/8 to 6-inch beds. Mudstone constitutes about five percent of the basal Venado.

Above the basal unit, mudstone beds increase to nearly 50 percent of the section. Further up the section, the Venado consists of repetitive intervals of medium to thick bedded sandstone and thinner bedded sandstone with subordinate mudstone (USBR 1969).

16

These bedded sandstones form the eastern ridge that is the current proposed location of Golden Gate Dam.



The mudstones of the Yolo shale member are laminated to thin-bedded, range from 800- to 1,000-feet thick, and occupy the strike valleys between the Venado and Sites sandstone members east of the dam sites.

Exposures of the Sites sandstone are located within 15 miles south of the reservoir area and consist of 1,500 to 2,000 feet of interbedded sandstone and siltstone. This sandstone member wedges out into a thick mudstone sequence about 8 miles south of the southern edge of the reservoir boundary.

## **Cenozoic Deposits**

The rocks of the Great Valley sequence have been eroded and, along the valleys and streams, have been partially covered with alluvial deposits and terraces of recent to middle Pleistocene age. These deposits were mapped in the project area by Helley and Harwood, (1985) and include recent stream channel deposits, Holocene alluvium and basin deposits, terraces of the Upper and Lower Modesto Formation, and Upper and Lower Riverbank Formation. The unit descriptions used by Helley and Harwood are summarized below. Stream channel deposits are active deposits of sand and gravel along streams and are without permanent vegetation. The Holocene alluvium consists of gravel, sand, and silt deposited by streams, and occurs outside of the stream channel deposits, but inside of the lowest terrace deposits. Basin deposits are fine-grained silt and clay derived from the same sources as the alluvium. The dark gray to black deposits are the distal facies of the alluvium.

The Upper and Lower Modesto Formation are the lowest distinct alluvial terraces lying topographically above the Holocene stream deposits. The Modesto includes tan and light gray gravelly sand, silt, and clay. The upper member is unconsolidated and unweathered, and it forms the topographically lowest terraces only a few meters thick. The surface preserves the original fluvial morphology with relief of 1-2 meters. The soils on the upper member have A/C horizons but lack an argillic B horizon. The lower member can be slightly weathered and forms terraces that are topographically higher than the upper member. The surface morphology is smooth and it is more extensive than the upper member. The soils on the lower member contain an argillic B horizon with an increase in clay content and red color.

The Riverbank Formation consists of weathered reddish gravel, sand, and silt. The Riverbank is differentiated from the younger Modesto by its terraces being topographically higher and by its more highly developed soil profile. The upper riverbank member is unconsolidated but compact dark brown to red alluvium, and forms the lower of the Riverbank terrace levels about 3 meters to 5 meters above the lower Modesto terrace. The lower member consists of red semi-consolidated gravel, sand, and silt. Its surface is higher and much more dissected than the upper member and has much stronger soil profiles.

## **Construction Materials**

Construction materials needed for the proposed embankment dams include impervious fill for the core, random fill, rockfill, riprap, filter and drain material, and aggregate for concrete structures. The terrace deposits upstream of the dam sites are the proposed source of the impervious material. Earlier reports by USBR

was estimated that 4.4 million cubic yards of impervious material were available within 1 mile of the Golden Gate Dam site and 2.8 mcy of impervious material were available within 1 mile of the Sites Dam site. This material would be from terrace deposits within the footprint of the reservoir.

Random or rockfill for Sites Dam was proposed to come from the existing Sites quarry in the Venado sandstone downstream of the dam site. Random fill for Golden Gate Dam was proposed to come from the ridge to the southeast of the originally proposed dam site. The current design uses this ridge as the abutment for the dam. Therefore, we are proposing using the northwest ridge of Venado sandstone for the rock quarry to supplement the materials excavated for the spillway and outlet works. This is within the footprint of the reservoir and would not result in additional environmental effects.

Testing of the Sites quarry materials indicate they are of relatively low strength, and have been identified by previous studies to lack wet-dry durability. The Sites quarry material has sufficient strength characteristics for use as rockfill, but may not be suitable for use as riprap without periodic maintenance. Wet-dry testing by the USBR found the material to have poor durability. DWR is presently conducting a wet-dry test to verify the USBR findings.

Preliminary indications are that the crushed quarried rock would probably not be suitable for the filter and drain material. During the spring of 1998, ten 3-inch cube samples of the quarry rock were collected for analysis. The results are summarized in Tables 8 and 9. During March 1999, approximately 5 yd³ each of the weathered and unweathered sandstone were crushed to 1.5-inch minus and taken to the Bryte Laboratory for further testing. During May 1999, ten rock cores each of the weathered and unweathered sandstone were collected from the Sites quarry. Further testing is being performed to assess the properties of the quarry rock. If it is not suitable, then filter and drain material would have to be brought from another source. Channel gravels associated with the active streams within the reservoir are too discontinuous to provide an adequate supply of gravel. The alternative source would include paleochannels of the Stony Creek fan that are being mined commercially. These operations are in Willows and Orland. Previously there was a commercial aggregate operation on Cortina Creek south of Williams.

Crushed quarried sandstone is not suitable for use as concrete aggregate. Concrete aggregate sources include the Stony Creek fan deposits described above.

Table 8. Results for Terrace Samples Collected Spring 1998

IMPERVIOUS MATERIALS									
SAMPLE LOCATION	Liquid Limits			TEST		Sample Description			
		Plasticity Index	Specific Gravity	Organic Content					
SC-1	38-45	23-27	2.78-2.79		Lean Clay to Sandy Lean Clay (CL)	Dark brown clayey silt, clay rich at 2 ft.; Clay sticky with small round pebbles at 6 ft. (Lower Modesto)			
SC-2	34-48	17-31	N/A		Lean Clay to Sandy Lean Clay (CL)	Dark clay, homogeneous at 4 ft.; weathered bedrock at 8ft			
SC-3	51-53	34-35	N/A		Fat Clay to Fat Clay with Sand (CH)	Dark brown silty clay, sticky at 2.5 ft.; weathered bedrock clayey, sticky yellowish gray at 6.5 ft.			
LC-1	33-44	17-25	2.77-2.83		Lean Clay to Sandy Lean Clay (CL)	Dark brown silty clay (Modesto) at 4.6 ft.; thick clay orange/brown rolls, in balls, possibly weathered bedrock, no chips at 8.0 ft.			
LC-2	34-44	17-29	N/A		Lean Clay to Lean Clay with Sand (CL)	dark brown organic loam at 1.5 ft.; clayey orange- brownish tan with scattered rounded gravel at 6.0 ft.			
GG-1	32-44	16-29	2.78-2.80	i e	Lean Clay with Sand (CL)	Light brown silty clay gravel layers (slight) caliche layer chunks (CaCO3) at 3.5 ft.; medium brown silty clay, caliche with small scattering of pebbles at 13.8 ft.; orangish brown clay layer, no pebbles, water flowing at 17.2 ft.			
GG-2	30-59	13-43	N/A		Sandy Lean Clay to Fat Clay (CL_CH)	Reddish brown silty clay scattered pebbles at 5.5 ft.; reddish weathered silty clay (Riverbank) at 11 ft.; gray to dark brown weathered clay with white mineralized CaCO3 or salts leaching out from groundwater at 15 ft.; blue clay in channel at 18 ft.			

Table 9. Results for Quarry Samples Collected Spring 1998

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QUARRY ROCK 3" CUBE SAMPLES									
Sample Number	Compressive Strength (psi)	Specific Gravity	Percent Absorption						
SSQ-1	9,960 - 11,130	2.48-2.50	2.6-2.8						
SSQ-2	11,690 - 12,370	2.49-2.50	2.5-2.6						
SSQ-3	No Sample								
SSQ-4	11,630 - 11,830	2.5	2.4-2.5						
SSQ-5	10,160 - 10,820	2.45-2.46	2.8-3.0						
SSQ-6	9,910 - 10,990	2.45	2.9-2.9						
SSQ-7	10,320 - 11,220	2.50-2.52	2.3-2.7						
SSQ-8	12,060 - 12,690	2.48-2.49	2.3-2.5						
SSQ-9	11,040 - 11,360	2.48-2.49	2.6-2.8						
SSQ-10	10,979 - 11,490	2.45-2.46	2.7-2.8						
Crushed Sandstone									
L.A. Rattler	1.5"x.375"	11.4% loss/100 rev.							
		43.4% loss/500 rev.							
Specific Gra	vity	2.48							
Absorption		4.20%							
Durability Ind	dex 0.75"x#4	Dc=42							
Specific Gra	vity	2.5							
Absorption		4.10%							

The aggregate testing indicates that both the fresh and weathered sandstone from Sites Quarry are poor quality materials for use as concrete aggregates. The average loss for both sandstones by the Los Angeles Rattler Test was greater that the 45 percent maximum allowable for concrete mix designs. USBR's poor soundness, and wet-dry results, further indicate the low quality as a concrete aggregate.

The investigation of sources for impervious material was performed by a detailed analysis of the aerial photographs taken May 12, 1997. Terrace boundaries were mapped for the three different geomorphic expressions that were recognized in the aerial photographs. The aerial photo interpretations were field checked, the terrace deposits along the incised stream channels in the project area were described, and the exposed thickness was measured. As a result of field checking, one additional terrace type was recognized.

The four terraces recognized for this investigation include from youngest to oldest:

A low terrace that occurs as small isolated remnants along the stream courses of Stone Coral, Antelope, and Funks Creeks between the bottom of the channel and the surface that occupies the valley floors. This terrace is generally 4 to 6 feet thick with weak soil development and consists of clayey

silt with some minor gravel. The color is generally very dark grayish brown (10YR3/2) to dark yellowish brown (10YR4/4). Gravel clasts are subangular sandstone displaying the original bedding planes. This terrace is tentatively correlated with the younger (upper) Modesto terrace of Helley and Harwood. This terrace was not extensive enough to show on Figures 5, 6, and 7.

The next terrace occurs as a broad, flat surface with very little relief occupying the floor of the valleys. This terrace is widespread in its lateral extent and is generally 12 to 20 feet thick although locally it is more than 30 feet thick. Soil development is greater than on the lower terrace but is still weak. The upper part of this terrace is clayey silt with increasing clay downward. Some gravel lenses were observed along the sides of the incised stream channels and in places there was a clay bed at the base of the observable deposit. The upper 2 to 3 feet is very dark grayish brown (10YR3/2 or 3), becoming lighter downward, brown or dark yellowish brown (10YR4/3 or 4). This terrace is tentatively correlated with the older (lower) Modesto terrace of Helley and Harwood. The map symbol for this terrace is Qlft (Quaternary low flat terrace).

The third terrace has very little surface relief but slopes gently up the tributary drainages. This terrace is generally thinner with observed thicknesses of 8 to 12 feet but the deposits resemble those of the Qlft surface. The upper 2 to 3 feet are dark clayey silts that grade downward to lighter silty clays. Colors are in the very dark grayish brown to brown range (10YR3 to 4), with weak soil development. This terrace is probably also Modesto in age. The map symbol for this surface is Qiss (Quaternary intermediate sloped surface).

The fourth terrace is found sporadically throughout the reservoir area generally above the valley floor. It usually has a sloped surface with some local relief. Observed thicknesses were generally 8 to 10 feet, but were as great as 25 feet along the western front of Logan Ridge and as little as 3 to 4 feet overlying the Boxer mudstone in some areas. Composition of this unit was generally clay to gravelly clay with the clasts subrounded to rounded, including red and black chert and igneous rocks. The color of this unit was usually brown to light brown (7.5 YR4 to 6). In several places this terrace is overlain by the Qlft surface, or the Qlft surface is cut into this surface. This terrace is tentatively correlated with the Riverbank terrace of Helley and Harwood. The map symbol for this terrace is Quss (Quaternary upper sloped surface).

Another surface was observed in the project area that consisted of horizontal, flat-lying ridge tops and notches. This surface was generally erosional on the Boxer Formation, contains no construction material, and was therefore disregarded for this report.

In spring 1998, terrace samples were collected at seven streambank exposures in Funks and Stone Corral Creeks. These samples were analyzed for Atterberg Limits, plasticity, specific gravity, and classification. Summary results are presented in Table 8.

Fifteen test pits were dug into the various terrace deposits in the Sites Reservoir area during the second week of June 1999. Generally three samples

were collected from each test pit for future laboratory analysis. Test pit logs are shown in Attachment A. Summary field descriptions of the samples are shown in Table 10. The results of the materials testing for these samples are included in Attachment D.

### **Sites Dam**

### **Impervious Materials**

The terrace deposits mapped in the Antelope Creek and Stone Corral Creek drainages within 5 miles of Sites Dam site are shown in Figure 5. The mapped area of the valley floor occupied by the Qlft terrace is 1,070 acres. With a conservative estimate of the thickness of the terrace of 10 feet, the volume of material in this terrace deposit is 17 million yd³. The field classification of this material is silty clay to clayey silt with a slight amount of gravel in the stream channel, and it appears to be suitable for the impervious fill zone. The volume of impervious material required for the Sites Dam is about 1 million cubic yards, which is 60 acres at 10 feet thick. This volume of material is available within 1 mile of the dam site.

Seven test pits were placed in the terrace deposits upstream from Sites Dam as shown in Figure 5. Four of the test pits encountered groundwater at depths of 10 to 16 feet and were terminated, two reached 16 feet with no groundwater, and one encountered bedrock at 12 feet. Generally there was a lack of stratification in the test pits with the material grading downward from clayey silt to silty clay. A clayey gravel was found in test pits SC-10 and SC-6 at 14 feet. There was no lithologic distinction observed between test pits in the Qlft surface and the Quss surface.

Soil classification tests and Atterberg limits were run on each of the test pit samples. The results are included in Attachment B. Generally the samples were classified as lean clay or lean clay with sand, USCS symbol CL. Six samples were classified as fat clay having liquid limits above 50.

#### Random Fill and Rockfill

The source of random fill and rockfill for Sites Dam is the Venado sandstone north of the existing Sites Quarry. Discounting the effects of swell and waste, a wedge of material in a parallelogram shape 300 feet wide by 300 feet high and 1,000 feet long at minimum would be needed to provide the 3.2 mcy random fill required. A quarry in the Venado sandstone was judged by DOE to produce both shell and random rockfill. By selective loading or processing with crushing and screening, it was estimated that the fresh sandstone would produce shell rockfill and the weathered sandstone, siltstone, and claystone would produce random rockfill. This quarry area is outside the footprint of the proposed reservoir area.

#### **Filter and Drain**

Filter and drain material will probably require aggregate from a source outside the vicinity of the reservoir area.

Table 10. Field Descriptions of Test Pit Samples<sup>1</sup>

SC4-1         SILT, clayey, slightly moist.         ML         10YR3/3           SC4-2         CLAY, silty.         CL         10YR3/6           SC4-3         CLAY, minor silt, slightly plastic, moist.         CL         10YR3/2           SC5-1         CLAY, minor silt, medium plastic, wet below ten feet.         CL         10YR3/3           SC6-1         CLAY, minor silt and gravel.         CL         10YR3/3           SC6-2         CLAY, minor silt and gravel.         CL         10YR4/3           SC6-3         CLAY, minor gravel.         CL         10YR4/3           SC6-3         CLAY, clayey gravel with minor sand, gravels are subrounded black chert & red sandstone.         CL         10YR4/2           SC7-1         CLAY, silty, sity, sew sand grains.         CL         10YR4/2           SC7-2         CLAY, silty, sew sand grains.         CL         10YR6/6           SC8-1         SILT, clayey, minor gravel, gravel lens in side wall.         ML         10YR3/3           SC8-2         CLAY, silty, with sand and gravel, angular.         SC         7.5YR5/4           SC8-3         CLAY, silty, with sand and gravel, angular.         SC         7.5YR5/8           SC8-1         SLT, clayey, slightly moist, calcareous streaking.         CL         2.5YR4/3 <t< th=""><th>SAMPLE #</th><th>DESCRIPTION</th><th>USCS<sup>2</sup></th><th>COLOR (MUNSELL)</th></t<>	SAMPLE #	DESCRIPTION	USCS <sup>2</sup>	COLOR (MUNSELL)
SC4-3         CLAY, minor silt, slightly plastic, moist.         CL         10YR3/2           SC5-1         CLAY, minor silt.         CL         10YR3/3           SC5-2         CLAY, minor silt, medium plastic, wet below ten feet.         CL         10YR3/3           SC6-1         CLAY, minor silt and gravel.         CL         10YR3/3           SC6-2         CLAY, minor gravel.         CL         10YR4/4           SC6-3         CLAY, clayey gravel with minor sand, gravels are subrounded black chert & red sandstone.         CL         10YR4/2           SC7-1         CLAY, silty, few sand grains.         CL         10/YR4/2           SC7-2         CLAY, minor silt, scattered fine gravel clasts, gastropod shell.         CL         10YR6/6           SC8-1         SILT, clayey, minor gravel, gravel lens in side wall.         ML         10YR3/3           SC8-2         CLAY, silty, with sand and gravel, angular.         SC         7.5YR5/8           SC8-3         CLAY, gravelly, rounded clast up to cobble in size.         GC         7.5YR5/8           SC9-1         CLAY, minor silt, slightly moist, calcareous streaking.         CL         2.5YR4/3           SC9-2         CLAY, minor silt, slightly moist, calcareous streaking.         CL         2.5YR4/2           SC10-3         SILT, clayey.         M	SC4-1	SILT, clayey, slightly moist.	ML	10YR3/3
SC5-1         CLAY, minor silt.         CL         10YR3/1           SC5-2         CLAY, very minor silt, medium plastic, wet below ten feet.         CL         10YR3/3           SC6-1         CLAY, minor silt and gravel.         CL         10YR3/3           SC6-2         CLAY, minor silt and gravel.         CL         10YR4/4           SC6-3         CLAY, clayey gravel with minor sand, gravels are subrounded black chert & red sandstone.         CL         7.5YR5/4           SC7-1         CLAY, silty, few sand grains.         CL         10/YR4/2           SC7-2         CLAY, minor silt, scattered fine gravel clasts, gastropod shell.         CL         10/YR6/6           SC8-1         SILT, clayey, minor gravel, gravel lens in side wall.         ML         10/YR3/3           SC8-2         CLAY, silty, with sand and gravel, angular.         SC         7.5YR5/8           SC8-3         CLAY, silty, with sand and gravel, angular.         SC         7.5YR5/8           SC8-3         CLAY, silty, minor silt, slightly moist, calcareous streaking.         GC         7.5YR5/8           SC9-2         CLAY, minor silt, slightly moist, calcareous streaking.         CL         2.5YR4/3           SC10-1         SILT, clayey.         ML         10YR3/4           SC10-2         CLAY, silty, moist, slidy moist, silty moist	SC4-2	CLAY, silty.	CL	10YR3/6
SC5-2         CLAY, very minor silt, medium plastic, wet below ten feet.         CL         10YR3/3           SC6-1         CLAY, minor silt and gravel.         CL         10YR 3/2           SC6-2         CLAY, minor gravel.         CL         10YR4/4           SC6-3         CLAY, clayey gravel with minor sand, gravels are subrounded black chert & red sandstone.         CL         7.5YR5/4           SC7-1         CLAY, silty, few sand grains.         CL         10YR6/6           SC7-2         CLAY, minor silt, scattered fine gravel clasts, gastropod shell.         CL         10YR6/6           SC8-1         SILT, clayey, minor gravel, gravel lens in side wall.         ML         10YR3/3           SC8-2         CLAY, silty, with sand and gravel, angular.         SC         7.5YR5/4           SC8-3         CLAY, gravelly, rounded clast up to cobble in size.         GC         7.5YR5/8           SC9-1         CLAY, minor silt, slightly moist, calcareous streaking.         CL         2.5YR4/2           SC9-2         CLAY, moist, plastic, some black mottling.         CL         2.5YR4/2           SC10-1         SILT, clayey.         ML         10YR3/4           SC10-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR4/4           GG1-3         GRAVEL, clayey. <td< td=""><td>SC4-3</td><td>CLAY, minor silt, slightly plastic, moist.</td><td>CL</td><td>10YR3/2</td></td<>	SC4-3	CLAY, minor silt, slightly plastic, moist.	CL	10YR3/2
SC6-1         CLAY, minor silt and gravel.         CL         10YR 3/2           SC6-2         CLAY, minor gravel.         CL         10YR4/4           SC6-3         CLAY, clayey gravel with minor sand, gravels are subrounded black chert & red sandstone.         CL         7.5YR5/4           SC7-1         CLAY, silty, few sand grains.         CL         10/YR4/2           SC7-2         CLAY, minor silt, scattered fine gravel clasts, gastropod shell.         CL         10YR6/6           SC8-1         SILT, clayey, minor gravel, gravel lens in side wall.         ML         10YR3/3           SC8-2         CLAY, silty, with sand and gravel, angular.         SC         7.5YR5/4           SC8-3         CLAY, gravelly, rounded clast up to cobble in size.         GC         7.5YR5/8           SC9-1         CLAY, minor, silt, slightly moist, calcareous streaking.         CL         2.5YR4/3           SC9-2         CLAY, moist, plastic, some black mottling.         CL         2.5YR4/3           SC10-1         SILT, clayey.         ML         10YR4/6           SC10-2         CLAY, minor, slit, slightly moist.         ML         10YR4/6           SC10-3         GRAVEL, clayey.         GC         10YR4/6           SC10-3         GRAVEL, clayey.         GC         10YR4/6	SC5-1	CLAY, minor silt.		10YR3/1
SC6-2         CLAY, minor gravel.         CL         10YR4/4           SC6-3         CLAY, clayey gravel with minor sand, gravels are subrounded black chert & red sandstone.         CL         7.5YR5/4           SC7-1         CLAY, silty, few sand grains.         CL         10/YR4/2           SC7-2         CLAY, minor silt, scattered fine gravel clasts, gastropod shell.         CL         10/YR6/6           SC8-1         SILT, clayey, minor gravel, gravel lens in side wall.         ML         10/YR3/3           SC8-2         CLAY, silty, with sand and gravel, angular.         SC         7.5YR5/4           SC9-3         CLAY, gravelly, rounded clast up to cobble in size.         GC         7.5YR5/8           SC9-1         CLAY, minor silt, slightly moist, calcareous streaking.         CL         2.5YR4/2           SC9-2         CLAY, minor silt, slightly moist, calcareous streaking.         CL         2.5YR4/2           SC10-1         SILT, clayey.         ML         10YR3/4           SC10-2         CLAY, silty.         CL         10YR4/6           SC10-3         GRAVEL, clayey.         GC         10YR4/4           SC1-1         SILT, clayey, slightly moist.         ML         10YR3/4           SC10-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4	SC5-2	CLAY, very minor silt, medium plastic, wet below ten feet.	CL	10YR3/3
SC6-3         CLAY, clayey gravel with minor sand, gravels are subrounded black chert & red sandstone.         CL         7.5YR5/4           SC7-1         CLAY, silty, few sand grains.         CL         10/YR4/2           SC7-2         CLAY, minor silt, scattered fine gravel clasts, gastropod shell.         CL         10YR6/6           SC8-1         SILT, clayey, minor gravel, gravel lens in side wall.         ML         10YR3/3           SC8-2         CLAY, silty, with sand and gravel, angular.         SC         7.5YR5/4           SC8-3         CLAY, gravelly, rounded clast up to cobble in size.         GC         7.5YR5/8           SC9-1         CLAY, minor silt, slightly moist, calcareous streaking.         CL         2.5YR4/3           SC9-2         CLAY, moist, plastic, some black mottling.         CL         2.5YR4/2           SC10-1         SILT, clayey.         ML         10YR3/4           SC10-2         CLAY, silty.         CL         10YR4/4           GC1-3         GRAVEL, clayey.         GC         10YR4/4           GG1-1         SILT, clayey, slightly plastic, some mottling.         CL         10YR4/4           GG1-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG2-1         SILT, clayey, slightly plastic.         CL         10YR4/4 <td>SC6-1</td> <td>CLAY, minor silt and gravel.</td> <td>CL</td> <td>10YR 3/2</td>	SC6-1	CLAY, minor silt and gravel.	CL	10YR 3/2
chert & red sandstone.         CLAY, silty, few sand grains.         CL         10/YR4/2           SC7-1         CLAY, silty, few sand grains.         CL         10/YR4/2           SC7-2         CLAY, minor silt, scattered fine gravel clasts, gastropod shell.         CL         10/YR6/6           SC8-1         SILT, clayey, minor gravel, gravel lens in side wall.         ML         10/YR3/3           SC8-2         CLAY, silty, with sand and gravel, angular.         SC         7.5YR5/4           SC8-3         CLAY, gravelly, rounded clast up to cobble in size.         GC         7.5YR5/8           SC9-1         CLAY, minor silt, slightly moist, calcareous streaking.         CL         2.5YR4/3           SC9-2         CLAY, minor, silt, some black mottling.         CL         2.5YR4/2           SC10-1         SILT, clayey.         ML         10YR3/4           SC10-2         CLAY, silty.         GC         10YR4/6           SC10-3         GRAVEL, clayey.         GC         10YR4/4           GG1-1         SILT, clayey, slightly moist.         ML         10YR8/4           GG1-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG2-1         SILT, clayey, slightly plastic.         CL         10YR4/4           GG2-2         CL	SC6-2	CLAY, minor gravel.	CL	10YR4/4
SC7-2         CLAY, minor silt, scattered fine gravel clasts, gastropod shell.         CL         10YR6/6           SC8-1         SILT, clayey, minor gravel, gravel lens in side wall.         ML         10YR3/3           SC8-2         CLAY, silty, with sand and gravel, angular.         SC         7.5YR5/8           SC8-3         CLAY, gravelly, rounded clast up to cobble in size.         GC         7.5YR5/8           SC9-1         CLAY, minor silt, slightly moist, calcareous streaking.         CL         2.5YR4/3           SC9-2         CLAY, moist, plastic, some black mottling.         CL         2.5YR4/2           SC10-1         SILT, clayey.         ML         10YR3/4           SC10-2         CLAY, silty.         CL         10YR4/6           SC10-3         GRAVEL, clayey.         GC         10YR4/4           GG1-1         SILT, clayey, slightly moist.         ML         10YR4/4           GG1-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR4/4           GG2-1         SILT, clayey, slightly moist.         ML         10YR4/4           GG2-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG2-3         CLAY, silty, moist, crumbly.         ML         10YR4/4           GG3-1	SC6-3		CL	7.5YR5/4
SC8-1         SILT, clayey, minor gravel, gravel lens in side wall.         ML         10YR3/3           SC8-2         CLAY, silty, with sand and gravel, angular.         SC         7.5YR5/4           SC8-3         CLAY, gravelly, rounded clast up to cobble in size.         GC         7.5YR5/8           SC9-1         CLAY, minor silt, slightly moist, calcareous streaking.         CL         2.5YR4/3           SC9-2         CLAY, moist, plastic, some black mottling.         CL         2.5YR4/3           SC10-1         SILT, clayey.         ML         10YR3/4           SC10-2         CLAY, silty.         CL         10YR4/6           SC10-3         GRAVEL, clayey.         GC         10YR4/6           SC10-3         GRAVEL, clayey.         GC         10YR4/6           GG1-1         SILT, clayey, slightly moist.         ML         10YR3/3           GG1-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR4/4           GG2-1         SILT, clayey, slightly moist.         ML         10YR4/2           GG2-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG3-1         SILT, clayey, slightly moist, crumbly.         ML         10YR3/3           GG3-2         SILT, clayey, slightly moist, slightly	SC7-1	CLAY, silty, few sand grains.	CL	10/YR4/2
SC8-2         CLAY, silty, with sand and gravel, angular.         SC         7.5YR5/4           SC8-3         CLAY, gravelly, rounded clast up to cobble in size.         GC         7.5YR5/8           SC9-1         CLAY, minor silt, slightly moist, calcareous streaking.         CL         2.5YR4/3           SC9-2         CLAY, moist, plastic, some black mottling.         CL         2.5YR4/2           SC10-1         SILT, clayey.         ML         10YR3/4           SC10-2         CLAY, silty.         CL         10YR4/6           SC10-3         GRAVEL, clayey.         GC         10YR4/4           GC1-1         SILT, clayey, slightly moist.         ML         10YR3/3           GG1-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR4/4           GG2-1         SILT, clayey, slightly moist.         ML         10YR4/2           GG2-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG3-1         SILT, clayey, slightly moist, crumbly.         ML         10YR3/3           GG3-2         SILT, clayey, slightly plastic.         CL         10YR4/4           GG3-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG4-1         CLAY, silty, moist, slightly moist, com	SC7-2	CLAY, minor silt, scattered fine gravel clasts, gastropod shell.	CL	10YR6/6
SC8-3         CLAY, gravelly, rounded clast up to cobble in size.         GC         7.5YR5/8           SC9-1         CLAY, minor silt, slightly moist, calcareous streaking.         CL         2.5YR4/3           SC9-2         CLAY, moist, plastic, some black mottling.         CL         2.5YR4/2           SC10-1         SILT, clayey.         ML         10YR3/4           SC10-2         CLAY, silty.         CL         10YR4/6           SC10-3         GRAVEL, clayey.         GC         10YR4/4           GC1-1         SILT, clayey, slightly moist.         ML         10YR3/3           GG1-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR4/4           GG2-1         SILT, clayey, slightly moist.         ML         10YR4/4           GG2-1         SILT, clayey, slightly moist.         ML         10YR4/2           GG2-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG3-3         CLAY, silty, moist, crumbly.         ML         10YR3/3           GG3-2         SILT, clayey.         ML         10YR4/4           GG4-1         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG4-1         CLAY, silty, slightly moist, stiff.         CL         10YR3/3 </td <td>SC8-1</td> <td>SILT, clayey, minor gravel, gravel lens in side wall.</td> <td>ML</td> <td>10YR3/3</td>	SC8-1	SILT, clayey, minor gravel, gravel lens in side wall.	ML	10YR3/3
SC9-1         CLAY, minor silt, slightly moist, calcareous streaking.         CL         2.5YR4/3           SC9-2         CLAY, moist, plastic, some black mottling.         CL         2.5YR4/2           SC10-1         SILT, clayey.         ML         10YR3/4           SC10-2         CLAY, silty.         CL         10YR4/6           SC10-3         GRAVEL, clayey.         GC         10YR4/4           GG1-1         SILT, clayey, slightly moist.         ML         10YR3/3           GG1-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR4/4           GG1-3         CLAY, minor silt.         CL         10YR4/4           GG2-1         SILT, clayey, slightly moist.         ML         10YR4/2           GG2-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG2-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG3-1         SILT, clayey, slightly moist, crumbly.         ML         10YR4/4           GG3-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/2           GG4-1         CLAY, silty, moist, slightly moist, stiff.         CL         10YR3/2           GG5-1         CLAY, silty, moist, slightly moist, crumbly.         ML	SC8-2	CLAY, silty, with sand and gravel, angular.	SC	7.5YR5/4
SC9-2         CLAY, moist, plastic, some black mottling.         CL         2.5YR4/2           SC10-1         SILT, clayey.         ML         10YR3/4           SC10-2         CLAY, silty.         CL         10YR4/6           SC10-3         GRAVEL, clayey.         GC         10YR4/4           GG1-1         SILT, clayey, slightly moist.         ML         10YR3/3           GG1-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR4/4           GG2-1         SILT, clayey, slightly moist.         ML         10YR4/2           GG2-1         SILT, clayey, slightly plastic.         CL         10YR4/4           GG2-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG3-3         SILT, clayey, slightly moist, crumbly.         ML         10YR3/3           GG3-2         SILT, clayey.         ML         10YR4/4           GG3-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG4-1         CLAY, silty, moist to wet.         CL         10YR4/2           GG4-2         CLAY, silty, wry moist to wet.         CL         10YR3/3           GG5-1         CLAY, silty, slightly moist, come mottling.         CL         10YR3/2           <	SC8-3	CLAY, gravelly, rounded clast up to cobble in size.	GC	7.5YR5/8
SC10-1         SILT, clayey.         ML         10YR3/4           SC10-2         CLAY, silty.         CL         10YR4/6           SC10-3         GRAVEL, clayey.         GC         10YR4/4           GG1-1         SILT, clayey, slightly moist.         ML         10YR3/3           GG1-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR4/4           GG2-3         CLAY, minor silt.         CL         10YR4/4           GG2-1         SILT, clayey, slightly moist.         ML         10YR4/2           GG2-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG2-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG3-1         SILT, clayey, slightly moist, crumbly.         ML         10YR3/3           GG3-2         SILT, clayey.         ML         10YR4/4           GG3-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG4-1         CLAY, silty, worst to wet.         CL         10YR3/4           GG5-1         CLAY, silty, slightly moist, stiff.         CL         10YR3/3           GG5-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR3/2           GG7	SC9-1	CLAY, minor silt, slightly moist, calcareous streaking.	CL	2.5YR4/3
SC10-2         CLAY, silty.         CL         10YR4/6           SC10-3         GRAVEL, clayey.         GC         10YR4/4           GG1-1         SILT, clayey, slightly moist.         ML         10YR3/3           GG1-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR4/4           GG1-3         CLAY, minor silt.         CL         10YR4/4           GG2-1         SILT, clayey, slightly moist.         ML         10YR4/2           GG2-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG2-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG3-1         SILT, clayey, slightly moist, crumbly.         ML         10YR3/3           GG3-2         SILT, clayey.         ML         10YR4/4           GG3-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG4-1         CLAY, silty, very moist to wet.         CL         10YR3/4           GG5-1         CLAY, silty, slightly moist, stiff.         CL         10YR3/3           GG5-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR3/2           GG7-1         SILT, clayey, slightly moist, crumbly.         ML         10YR3/2     <	SC9-2	CLAY, moist, plastic, some black mottling.	CL	2.5YR4/2
SC10-3         GRAVEL, clayey.         GC         10YR4/4           GG1-1         SILT, clayey, slightly moist.         ML         10YR3/3           GG1-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR4/4           GG1-3         CLAY, minor silt.         CL         10YR4/4           GG2-1         SILT, clayey, slightly moist.         ML         10YR4/2           GG2-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG2-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG3-1         SILT, clayey, slightly moist, crumbly.         ML         10YR3/3           GG3-2         SILT, clayey.         ML         10YR4/4           GG3-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG4-1         CLAY, silty, wory moist to wet.         CL         10YR3/4           GG5-1         CLAY, silty, slightly moist, stiff.         CL         10YR3/3           GG5-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR3/2           GG7-1         SILT, clayey, slightly moist, crumbly.         ML         10YR3/2           GG7-2         SILT, clayey.         ML         10YR4/4     <	SC10-1	SILT, clayey.	ML	10YR3/4
GG1-1         SILT, clayey, slightly moist.         ML         10YR3/3           GG1-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR4/4           GG1-3         CLAY, minor silt.         CL         10YR4/4           GG2-1         SILT, clayey, slightly moist.         ML         10YR4/2           GG2-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG2-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG3-1         SILT, clayey, slightly moist, crumbly.         ML         10YR4/4           GG3-2         SILT, clayey.         ML         10YR4/4           GG3-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG4-1         CLAY, silty, moist.         CL         10YR4/2           GG4-2         CLAY, silty, slightly moist, stiff.         CL         10YR3/3           GG5-1         CLAY, silty, slightly moist, slightly plastic, some mottling.         CL         10YR4/4           GG6-1         CLAY, silty, slightly moist, crumbly.         ML         10YR3/2           GG7-2         SILT, clayey.         ML         10YR4/4           GG7-3         CLAY, silty, moist, slightly plastic.         CL         1	SC10-2	CLAY, silty.	CL	10YR4/6
GG1-2CLAY, silty, moist, slightly plastic, some mottling.CL10YR4/4GG1-3CLAY, minor silt.CL10YR4/4GG2-1SILT, clayey, slightly moist.ML10YR4/2GG2-2CLAY, silty, moist, slightly plastic.CL10YR4/4GG2-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG3-1SILT, clayey, slightly moist, crumbly.ML10YR3/3GG3-2SILT, clayey.ML10YR4/4GG3-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG4-1CLAY, silty, moist to wet.CL10YR3/4GG5-1CLAY, silty, slightly moist, stiff.CL10YR3/3GG5-2CLAY, silty, moist, slightly plastic, some mottling.CL10YR3/2GG7-1SILT, clayey, slightly moist, crumbly.CL10YR3/2GG7-2SILT, clayey.ML10YR3/2GG7-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG7-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG8-1CLAY, silty, moist, slightly plastic.CL10YR4/4GG7-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG8-1CLAY, silty, moist, slightly plastic.CL10YR4/4GG8-1CLAY, silty, gravel clasts - fine to medium.CL10YR4/2	SC10-3	GRAVEL, clayey.	GC	10YR4/4
GG1-3         CLAY, minor silt.         CL         10YR4/4           GG2-1         SILT, clayey, slightly moist.         ML         10YR4/2           GG2-2         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG2-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG3-1         SILT, clayey, slightly moist, crumbly.         ML         10YR4/4           GG3-2         SILT, clayey.         ML         10YR4/4           GG3-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG4-1         CLAY, silty, wry moist to wet.         CL         10YR3/4           GG5-1         CLAY, silty, slightly moist, stiff.         CL         10YR3/3           GG5-2         CLAY, silty, moist, slightly plastic, some mottling.         CL         10YR3/2           GG5-1         CLAY, silty, slightly moist, tough.         CL         10YR3/2           GG7-1         SILT, clayey, slightly moist, crumbly.         ML         10YR3/2           GG7-2         SILT, clayey.         ML         10YR4/4           GG7-3         CLAY, silty, moist, slightly plastic.         CL         10YR4/4           GG8-1         CLAY, silty, gravel clasts - fine to medium.         CL	GG1-1	SILT, clayey, slightly moist.	ML	10YR3/3
GG2-1SILT, clayey, slightly moist.ML10YR4/2GG2-2CLAY, silty, moist, slightly plastic.CL10YR4/4GG2-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG3-1SILT, clayey, slightly moist, crumbly.ML10YR3/3GG3-2SILT, clayey.ML10YR4/4GG3-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG4-1CLAY, silty, moist.CL10YR4/2GG4-2CLAY, silty, very moist to wet.CL10YR3/4GG5-1CLAY, silty, moist, slightly moist, stiff.CL10YR3/3GG5-2CLAY, silty, moist, slightly plastic, some mottling.CL10YR4/4GG6-1CLAY, silty, slightly moist, tough.CL10YR3/2GG7-1SILT, clayey, slightly moist, crumbly.ML10YR3/2GG7-2SILT, clayey.ML10YR4/4GG7-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG8-1CLAY, silty, gravel clasts - fine to medium.CL10YR4/2	GG1-2	CLAY, silty, moist, slightly plastic, some mottling.	CL	10YR4/4
GG2-2 CLAY, silty, moist, slightly plastic.  GG2-3 CLAY, silty, moist, slightly plastic.  GG3-1 SILT, clayey, slightly moist, crumbly.  GG3-2 SILT, clayey.  ML 10YR4/4  GG3-3 CLAY, silty, moist, slightly plastic.  CL 10YR4/4  GG3-3 CLAY, silty, moist, slightly plastic.  CL 10YR4/4  GG4-1 CLAY, silty, wery moist to wet.  GG4-2 CLAY, silty, very moist to wet.  GG5-1 CLAY, silty, slightly moist, stiff.  CL 10YR3/3  GG5-2 CLAY, silty, moist, slightly plastic, some mottling.  GG6-1 CLAY, silty, slightly moist, tough.  GG7-1 SILT, clayey, slightly moist, crumbly.  GG7-2 SILT, clayey.  GG7-3 CLAY, silty, moist, slightly plastic.  CL 10YR4/4  GG8-1 CLAY, silty, moist, slightly plastic.  CL 10YR4/4  CG7-3 CLAY, silty, moist, slightly plastic.  CL 10YR4/4  CCL 10YR4/4  CCL 10YR4/4  CCL 10YR4/4	GG1-3	CLAY, minor silt.	CL	10YR4/4
GG2-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG3-1SILT, clayey, slightly moist, crumbly.ML10YR3/3GG3-2SILT, clayey.ML10YR4/4GG3-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG4-1CLAY, silty, moist.CL10YR4/2GG4-2CLAY, silty, very moist to wet.CL10YR3/4GG5-1CLAY, silty, slightly moist, stiff.CL10YR3/3GG5-2CLAY, silty, moist, slightly plastic, some mottling.CL10YR4/4GG6-1CLAY, silty, slightly moist, tough.CL10YR3/2GG7-1SILT, clayey, slightly moist, crumbly.ML10YR3/2GG7-2SILT, clayey.ML10YR4/4GG7-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG8-1CLAY, silty, gravel clasts - fine to medium.CL10YR4/2	GG2-1	SILT, clayey, slightly moist.	ML	10YR4/2
GG3-1SILT, clayey, slightly moist, crumbly.ML10YR3/3GG3-2SILT, clayey.ML10YR4/4GG3-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG4-1CLAY, silty, moist.CL10YR4/2GG4-2CLAY, silty, very moist to wet.CL10YR3/4GG5-1CLAY, silty, slightly moist, stiff.CL10YR3/3GG5-2CLAY, silty, moist, slightly plastic, some mottling.CL10YR4/4GG6-1CLAY, silty, slightly moist, tough.CL10YR3/2GG7-1SILT, clayey, slightly moist, crumbly.ML10YR3/2GG7-2SILT, clayey.ML10YR4/4GG7-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG8-1CLAY, silty, gravel clasts - fine to medium.CL10YR4/2	GG2-2	CLAY, silty, moist, slightly plastic.	CL	10YR4/4
GG3-2SILT, clayey.ML10YR4/4GG3-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG4-1CLAY, silty, moist.CL10YR4/2GG4-2CLAY, silty, very moist to wet.CL10YR3/4GG5-1CLAY, silty, slightly moist, stiff.CL10YR3/3GG5-2CLAY, silty, moist, slightly plastic, some mottling.CL10YR4/4GG6-1CLAY, silty, slightly moist, tough.CL10YR3/2GG7-1SILT, clayey, slightly moist, crumbly.ML10YR3/2GG7-2SILT, clayey.ML10YR4/4GG7-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG8-1CLAY, silty, gravel clasts - fine to medium.CL10YR4/2	GG2-3	CLAY, silty, moist, slightly plastic.	CL	10YR4/4
GG3-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG4-1CLAY, silty, moist.CL10YR4/2GG4-2CLAY, silty, very moist to wet.CL10YR3/4GG5-1CLAY, silty, slightly moist, stiff.CL10YR3/3GG5-2CLAY, silty, moist, slightly plastic, some mottling.CL10YR4/4GG6-1CLAY, silty, slightly moist, tough.CL10YR3/2GG7-1SILT, clayey, slightly moist, crumbly.ML10YR3/2GG7-2SILT, clayey.ML10YR4/4GG7-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG8-1CLAY, silty, gravel clasts - fine to medium.CL10YR4/2	GG3-1	SILT, clayey, slightly moist, crumbly.	ML	10YR3/3
GG4-1 CLAY, silty, moist.  GG4-2 CLAY, silty, very moist to wet.  GG5-1 CLAY, silty, slightly moist, stiff.  GG5-2 CLAY, silty, moist, slightly plastic, some mottling.  GG6-1 CLAY, silty, slightly moist, tough.  GG7-1 SILT, clayey, slightly moist, crumbly.  GG7-2 SILT, clayey.  GG7-3 CLAY, silty, moist, slightly plastic.  GG8-1 CLAY, silty, moist, crumbly.  ML 10YR3/2  GG7-3 CLAY, silty, moist, slightly plastic.  CL 10YR4/4  CL 10YR4/4  CL 10YR4/4	GG3-2	SILT, clayey.	ML	10YR4/4
GG4-2CLAY, silty, very moist to wet.CL10YR3/4GG5-1CLAY, silty, slightly moist, stiff.CL10YR3/3GG5-2CLAY, silty, moist, slightly plastic, some mottling.CL10YR4/4GG6-1CLAY, silty, slightly moist, tough.CL10YR3/2GG7-1SILT, clayey, slightly moist, crumbly.ML10YR3/2GG7-2SILT, clayey.ML10YR4/4GG7-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG8-1CLAY, silty, gravel clasts - fine to medium.CL10YR4/2	GG3-3	CLAY, silty, moist, slightly plastic.	CL	10YR4/4
GG5-1CLAY, silty, slightly moist, stiff.CL10YR3/3GG5-2CLAY, silty, moist, slightly plastic, some mottling.CL10YR4/4GG6-1CLAY, silty, slightly moist, tough.CL10YR3/2GG7-1SILT, clayey, slightly moist, crumbly.ML10YR3/2GG7-2SILT, clayey.ML10YR4/4GG7-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG8-1CLAY, silty, gravel clasts - fine to medium.CL10YR4/2	GG4-1	CLAY, silty, moist.	CL	10YR4/2
GG5-2 CLAY, silty, moist, slightly plastic, some mottling.  GG6-1 CLAY, silty, slightly moist, tough.  GG7-1 SILT, clayey, slightly moist, crumbly.  GG7-2 SILT, clayey.  GG7-3 CLAY, silty, moist, slightly plastic.  GG8-1 CLAY, silty, gravel clasts - fine to medium.  CL 10YR4/4  CL 10YR4/4  CL 10YR4/2	GG4-2	CLAY, silty, very moist to wet.	CL	10YR3/4
GG6-1CLAY, silty, slightly moist, tough.CL10YR3/2GG7-1SILT, clayey, slightly moist, crumbly.ML10YR3/2GG7-2SILT, clayey.ML10YR4/4GG7-3CLAY, silty, moist, slightly plastic.CL10YR4/4GG8-1CLAY, silty, gravel clasts - fine to medium.CL10YR4/2	GG5-1	CLAY, silty, slightly moist, stiff.	CL	10YR3/3
GG7-1 SILT, clayey, slightly moist, crumbly.  GG7-2 SILT, clayey.  ML 10YR3/2  GG7-3 CLAY, silty, moist, slightly plastic.  CL 10YR4/4  GG8-1 CLAY, silty, gravel clasts - fine to medium.  CL 10YR4/2	GG5-2	CLAY, silty, moist, slightly plastic, some mottling.	CL	10YR4/4
GG7-2 SILT, clayey. ML 10YR4/4 GG7-3 CLAY, silty, moist, slightly plastic. CL 10YR4/4 GG8-1 CLAY, silty, gravel clasts - fine to medium. CL 10YR4/2	GG6-1	CLAY, silty, slightly moist, tough.	CL	10YR3/2
GG7-3 CLAY, silty, moist, slightly plastic. CL 10YR4/4 GG8-1 CLAY, silty, gravel clasts - fine to medium. CL 10YR4/2	GG7-1	SILT, clayey, slightly moist, crumbly.	ML	10YR3/2
GG8-1 CLAY, silty, gravel clasts - fine to medium. CL 10YR4/2	GG7-2	SILT, clayey.	ML	10YR4/4
GG8-1 CLAY, silty, gravel clasts - fine to medium. CL 10YR4/2	GG7-3	CLAY, silty, moist, slightly plastic.	CL	10YR4/4
	GG8-1	4	CL	10YR4/2
	GG8-2	2	bedrock	

<sup>&</sup>lt;sup>1</sup> Sample locations are shown on Figures 5, 6, and 7.
<sup>2</sup> Unified Soil Classification System

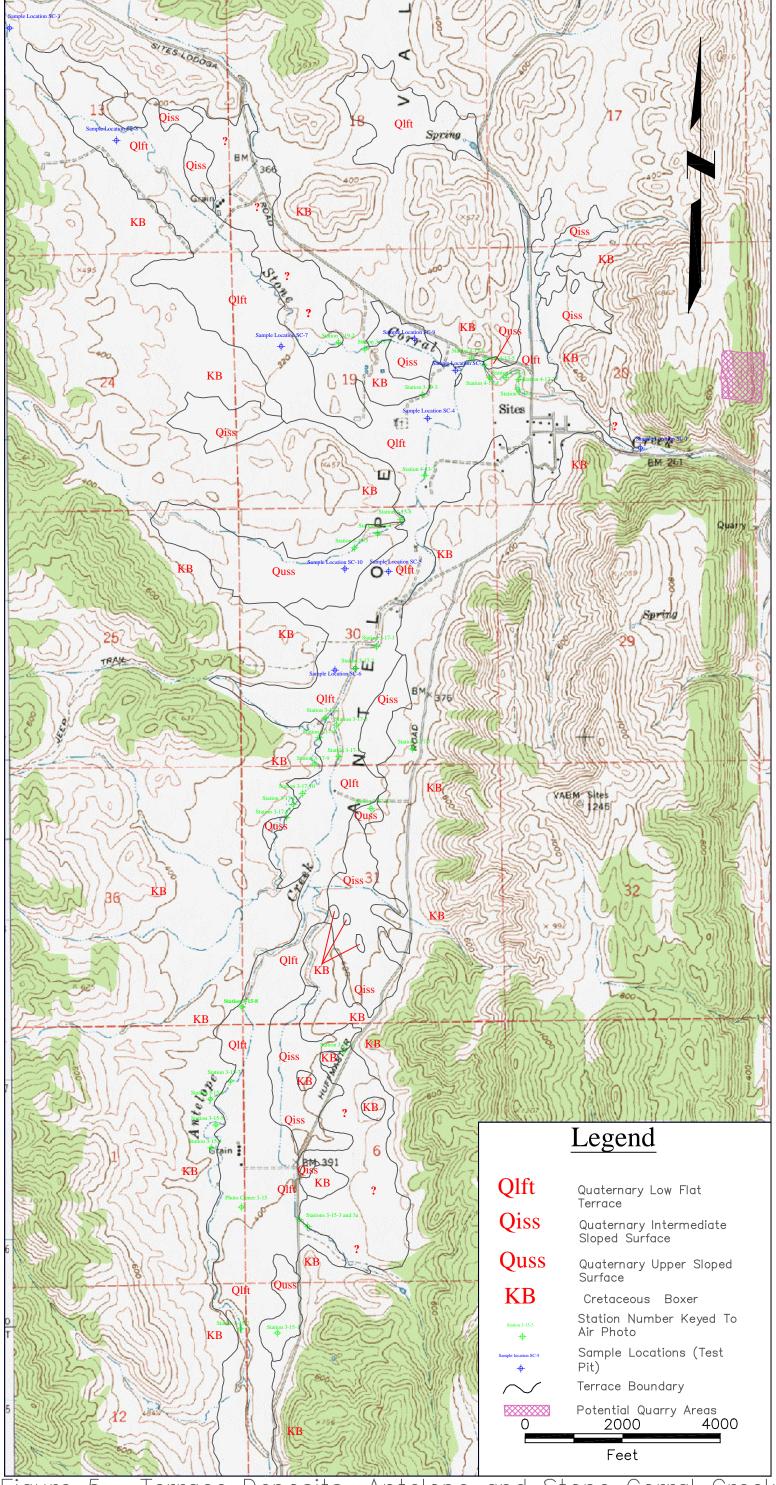


Figure 5. Terrace Deposits, Antelope and Stone Corral Creeks

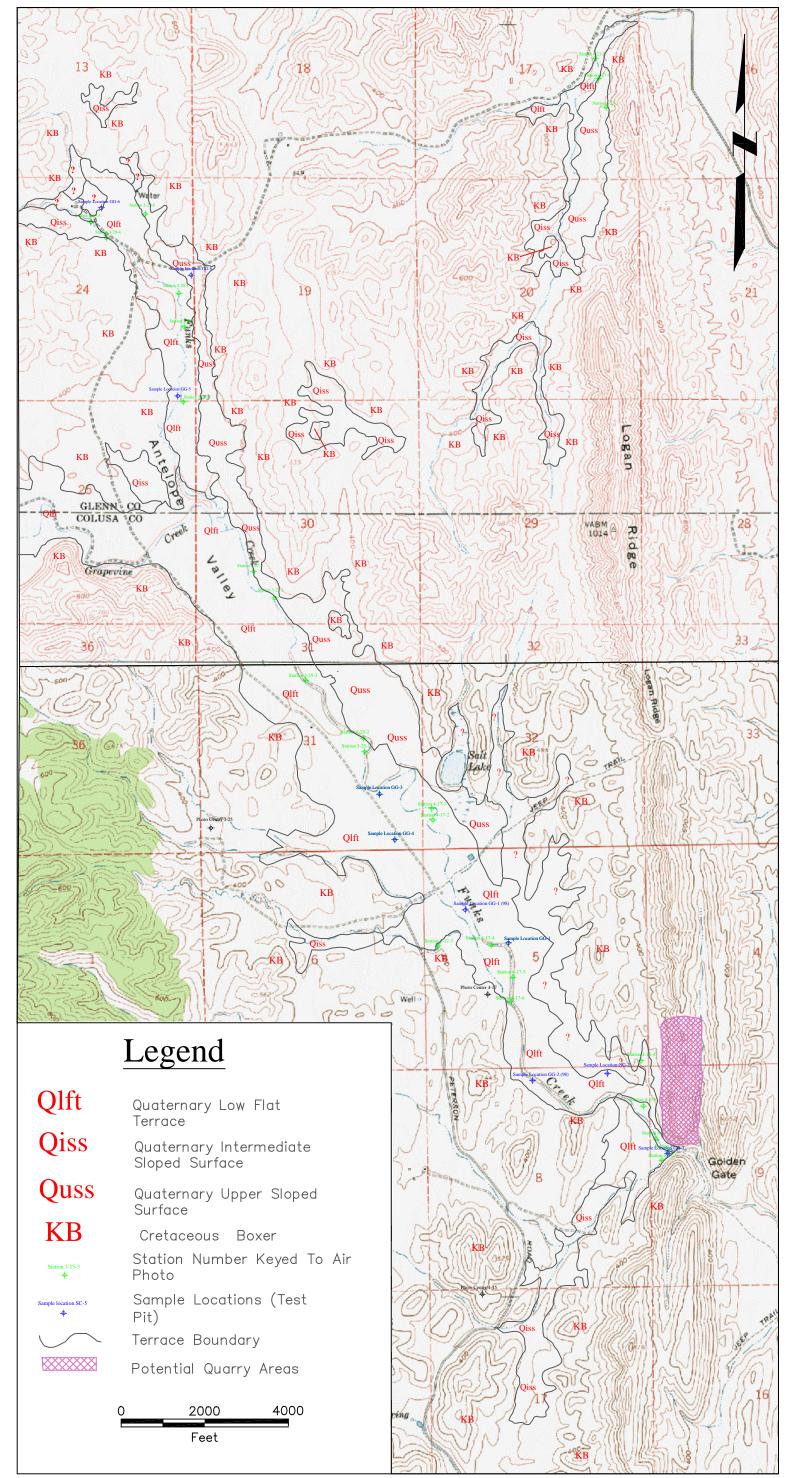


Figure 6. Terrace deposits, Funks and Grapevine Creeks

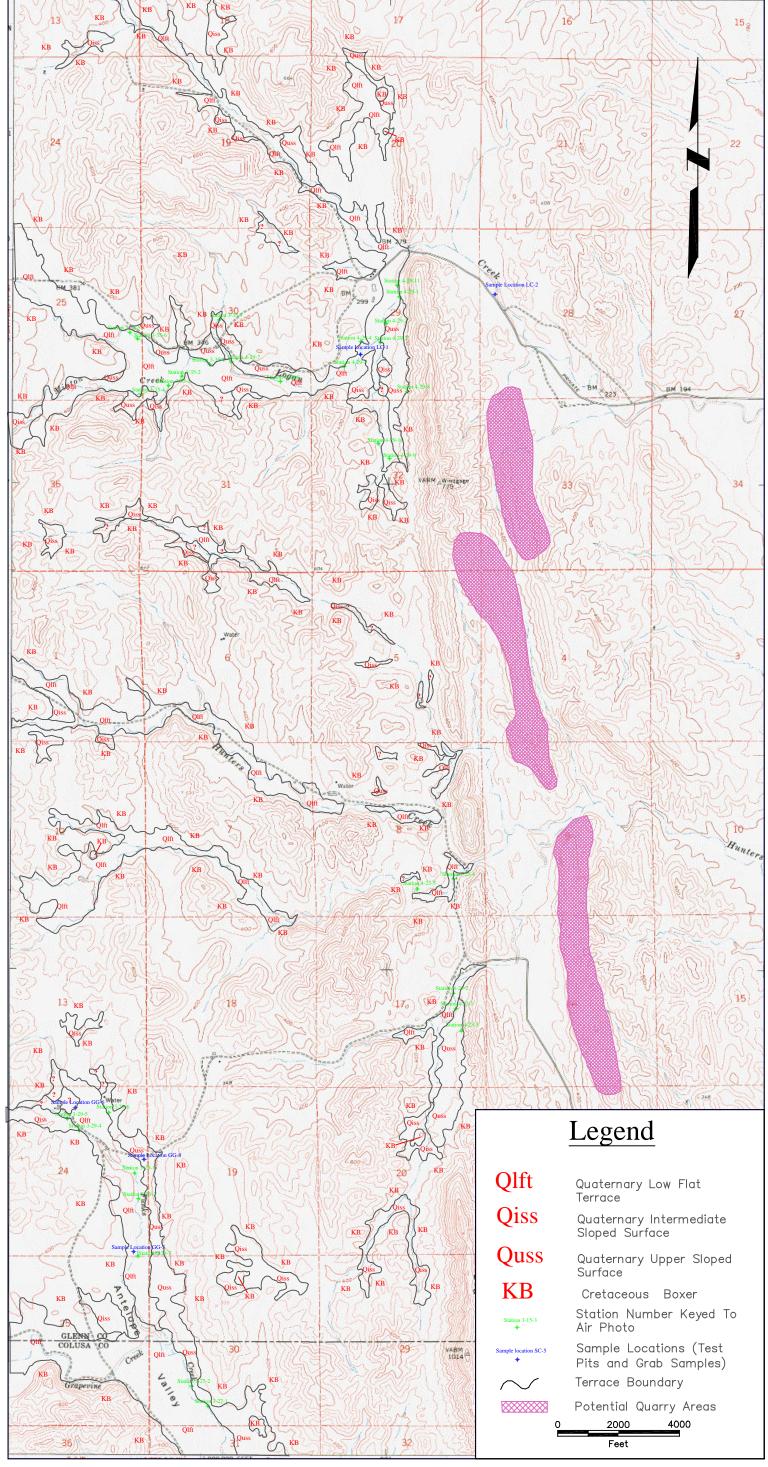


Figure 7. Terrace Deposits Hunters and Logan Creeks

#### **Golden Gate Dam**

#### **Impervious Materials**

Terrace deposits mapped in the Funks Creek drainage within 3 miles of the dam site are shown in Figure 6. The mapped area of the valley floor occupied by the Qlft terrace is 628 acres. With a conservative estimate of 10 feet for the terrace thickness, the volume of material in this terrace deposit is 10 million yd³. The field classification of this material is silty clay to clayey silt with some gravel in the stream channel, and it appears to be suitable for the impervious fill zone. The material along Funks Creek appears to have more silt content in the upper 10 feet than the Stone Corral/Antelope Creek material. The volume required for the Golden Gate Dam is about 2,552,000 yd³, which is 158 acres at 10 feet thick (3.5 mcy for the downstream curved alignment, 220 acres). This volume of material is available within 1 mile of the dam site.

Five test pits were placed along Funks Creek within 2 miles of the Golden Gate Dam site. Two test pits encountered groundwater at 8 to 14 feet and were terminated, two reached 18 feet and one reached 20 feet. The lithologies were mostly clayey silt with increasing clay content downward. Samples from GG-4 were clay rich. All test pits were placed in the Qlft surface.

Soil classification tests and Atterberg limits were run on each test pit sample. The results are included in Attachment B. All the samples were classified as lean clay or lean clay with sand, Unified Soil Classification System symbol CL.

#### Random Fill

The proposed source of the random fill for Golden Gate Dam is the Venado sandstone to the northwest of the downstream alignment. Discounting the effects of swell and waste, a wedge of material in a parallelogram shape, 300 feet wide by 300 feet high and 2,400 feet long at a minimum, would be required to provide the 8 million yd³ of random fill required. No testing has been performed on this quarry site but its properties should be similar to the Sites Quarry. A quarry in the Venado sandstone was judged by DOE to produce both shell and random rockfill. By selective loading or processing with crushing and screening, it was estimated that the fresh sandstone would produce shell rockfill and the weathered sandstone, siltstone, and claystone would produce random rockfill. This quarry is inside the reservoir footprint.

#### **Filter and Drain**

Filter and drain material will probably require aggregate from a source outside the vicinity of the dam site.

#### **Concrete Aggregate**

Sample results indicate that crushed Venado sandstone will not be suitable for use as concrete aggregate. The nearest commercial sources of aggregate are on the Stony Creek fan between Willows and Artois and near Orland. Stony Creek aggregate has been found suitable for use with high-alkali cement and has been used in the construction of East Park Dam, Stony Gorge Dam, and Black Butte

Dam. Currently permitted reserves of Stony Creek aggregate are 61 million tons with a total estimated reserve of 1,031 million tons (Glenn County ARMP 1997).

In addition to commercial sources on the Stony Creek fan, it is estimated that 41 million tons of sand and gravel are impounded behind Black Butte Dam. These deposits probably contain a higher amount of silt and clay and would need to be cleaned before use. Extraction of these deposits would result in an increase in capacity of Black Butte Reservoir. Similar conditions exist on East Park Reservoir 20 miles west of Sites.

There was a commercial gravel operation on Cortina Creek south of Williams that has closed. The quantity and quality of aggregate that may be available along Cortina Creek is unknown.

### Saddle Dams

## **Impervious Materials**

The terrace deposits mapped in the middle Funks Creek and Grapevine Creek drainages are shown in Figure 6. The mapped area of the valley floor occupied by the Qlft terrace is 461 acres. With a conservative estimate of the thickness of the terrace of 10 feet, the volume of material in this terrace deposit is 7,437,500 yd³. The field classification of this material is silty clay to clayey silt with some gravel in the stream channel, and it appears to be suitable for the impervious fill zone. The volume required for the saddle dams is about 2,626,000 yd³, which is 162 acres at 10 feet thick. This volume of material is available along Funks Creek generally within 1 mile of the saddle dam alignment.

Three test pits were placed toward the northern end of Funks Creek near the saddle dam alignment. Bedrock was encountered at 6 feet in GG-6 and 9 feet in GG-8, and groundwater was encountered at 10 feet in GG-5. The lithology of the terrace deposits was silty clay. Test pits GG-6 and GG-8 were placed in the Quss surface and GG-5 in the Qlft surface.

Soil classification tests and Atterberg limits were run on each test pit sample. The results are included in Attachment B. One sample from each test pit was classified as fat clay, USCS symbol CH.

#### Random Fill

The proposed source of random fill for saddle dams is the Venado sandstone ridge northwest of the proposed Golden Gate Dam. A wedge of material in a parallelogram shape 300 feet wide by 300 feet high and 1,400 feet long would be required to provide 4.6 mcy of fill. No testing has been performed on this quarry site but its properties should be similar to the Sites quarry.

This quarry is inside the reservoir footprint and is the same quarry that would provide random fill material for Golden Gate Dam. Haul distance to the major saddle dams would be 1 to 3 miles.

34

#### **Drain and Transition**

There is a possibility that the transition material can be supplied by crushed Venado sandstone. Drain material will probably require aggregate from a source outside the vicinity of the dam site.

### **Colusa Reservoir Dams**

#### **Impervious Materials**

The terrace deposits mapped in the Hunters, Logan, and Minton Creeks and other unnamed drainages are shown on Figure 7. The mapped area of the valley floors occupied by the Qlft terrace is 964 acres. Assuming the terrace thickness is 10 feet, the volume of material in these terrace deposits is about 15 million yd³. The terrace deposits along the drainages in the Colusa Reservoir area are not as extensive as those along Funks, Stone Corral, and Antelope Creeks. The field classification of the terrace material exposed in the incised stream channels is silty clay to clayey silt with some gravel.

The volume of impervious fill required for the Hunters and Logan Dams and the Colusa saddle dams is 13,200,000 yd³, which is 818 acres at 10 feet thick. Haul distances of 3 or more miles will be required to transport this material to the dam sites. Nearly all of the Qlft terrace deposits inside the reservoir footprint will be required. Another potential source of impervious fill material is the deposits of weathered Boxer Formation mudstones that occur in the area. Some of these deposits have been observed with thicknesses of 12 or more feet.

No test pits have been placed in the Colusa Reservoir footprint for material testing and classification.

#### Random Fill

A source for the random fill for the dams for the Colusa complex has not yet been identified. The required volume of material is approximately 60,000,000 yd³. This volume of Venado sandstone is not available within the reservoir footprint. There are some Boxer sandstones mapped along the western margin of the reservoir, but these are also outside the footprint. The ridges of Venado sandstone upon which the Hunters Dam and Logan Dam are based are single ridges, not double ridges like the Golden Gate Dam and Sites Dam sites. Using the analogy of a ridge quarry of 300 by 300 feet, a ridge over 3 miles long would be required to supply the required volume of material. There is a 250-foot-high ridge about 1/2 to 3/4 mile east of Hunters Dam site that apparently consists of sandstone beds that could provide a source for the random fill. This ridge has not been mapped or sampled for an evaluation of its properties. It would also require an environmental study as it is outside the reservoir footprint.

### **Drain and Transition**

There is a possibility that the transition material can be supplied by crushed Venado sandstone. Drain material will probably require aggregate from a source outside the vicinity of the dam site.

## **Conclusions**

Construction materials in the vicinity were investigated for the Sites Project. Materials required include impervious core, random fill, shell and rockfill, and filter and drain. The geologic materials investigated include terrace deposits, sandstone beds, and sand and gravel deposits. For Sites Dam, Golden Gate Dam, and the saddle dams, there is an adequate reserve of terrace deposits with the appropriate properties to supply the material for the impervious core. There is an adequate quantity of quarry sandstone either within or just outside of the reservoir to supply the random rock. The sandstone may be of marginal quality to provide the shell zone, and it is undergoing further testing. Degradation of the shell by weathering of the exposed rock should be expected during the life of the structure and may require selective replacement. If the sandstone will not meet properties needed for pervious shell material, the preliminary zoned rockfill design will have to be revised or, another source would be required. Sources of stronger rock have not yet been investigated. Filter and drain and concrete aggregate would need to be provided from sand and gravel deposits outside the reservoir area. Adequate reserves of developable sand and gravel exist on the Stony Creek fan in the vicinity of Willows and Orland.

A reconnaissance-level investigation was performed for construction materials for the Colusa Reservoir dams. Required materials include impervious core, random fill, rockfill, filter, and drain. For Hunters Dam and Logan Dam, the volume of nearby terrace deposits for the impervious core equal the volume required. Terrace deposits have not been sampled. The source of the random fill has not been identified. Sandstone beds of the Cortina Formation do not exist within the reservoir footprint in the Colusa Cell of the reservoir and the ridge occupied by the dam is a single ridge. There is a ridge about 1/2 mile east of Hunters Dam but it has not been mapped or sampled. Filter and drain, and concrete aggregate would need to be provided from sand and gravel deposits outside the reservoir area. Adequate reserves of developable sand and gravel exist on the Stony Creek fan in the vicinity of Willows and Orland.

## Recommendations

#### Sites Dam

- Detailed geologic mapping of sandstone quarry area to estimate sandstone versus mudstone volume. May include limited drilling.
- Sample and test weathered and unweathered mudstone to determine physical properties to establish whether it can be used as random or rock fill.
- Perform further tests on the sandstone to establish whether it can be used as the dam's upstream shell.

## **Golden Gate Dam**

- Detailed geologic mapping of sandstone quarry area (may be spillway alignment) to estimate sandstone versus mudstone volume. May include limited drilling.
- Sample and test weathered and unweathered mudstone to determine physical properties to establish whether it can be used as random or rock fill.
- Perform further tests on the sandstone to establish whether it can be used as the dam's upstream shell.
- Sample sandstone to confirm properties are consistent with those of rock from Sites quarry area.

## **Hunters and Logan Dams**

- Test pit, sample and analyze terrace deposits.
- Map areas of thick soil development on the Boxer Formation.
- Test pit, sample and analyze thick soils.
- Obtain right of entry to Logan Land and Cattle Co. property east of Hunters Dam, and map sandstone ridge that is potential source of random fill.
- Sample and test sandstone and mudstone from ridge.
- If sandstone is suitable for random fill, then perform full environmental analysis of ridge (botanical, biological, cultural, etc.).

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38